SPECIFICATION

TITLE

"ANTENNA ELEMENT AND ANTENNA ARRANGEMENT FOR MAGNETIC RESONANCE APPLICATIONS"

BACKGROUND OF THE INVENTION

Field Of The Invention

The present invention concerns an antenna element for magnetic resonance applications of the type having a sub-section extending along a section axis. The present invention also concerns an antenna arrangement for magnetic resonance applications with a number of such antenna elements parallel to one another.

Antenna elements for magnetic resonance applications and corresponding antenna arrangements are generally known. In particular, the antenna elements can be fashioned as antenna rods of a birdcage resonator or as axially proceeding parts of a saddle coil.

In magnetic resonance applications, radio-frequency coils (resonators) are used for the excitation and the reception of radio-frequency alternating magnetic fields. In addition to a homogenous static magnetic field, an optimally homogenous radio-frequency field is also required for imaging. For example, cylindrical radio-frequency coils (birdcage resonators, saddle coils) exhibit a very homogenous radio-frequency profile.

Non-uniform loading of the radio-frequency coils, electrical shielding and dielectric resonance in the examination subject can lead to different

excitations of the magnetic resonances. Such different excitations lead to effects known as shadowing effects (shadows) in the generated images.

For high-resolution exposures, it is therefore not sufficient to keep the current distribution on the antenna elements of the radio-frequency coil (or the antenna arrangement) constant. Rather, it can be necessary to individually adjust the current distribution, in particular dependent on the examination subject.

SUMMARY OF THE INVENTION

An object of the present invention is to provide an antenna element in which the current distribution can be adjusted along the section axis.

This object is achieved by an antenna element having a sub-section extending along a section axis, wherein a first auxiliary circuit is arranged adjacent to the first sub-section, the first auxiliary circuit having a coupling section and an auxiliary circuit section, and being inductively coupled to the first sub-section via the coupling section, with the auxiliary circuit section proceeding parallel to the first sub-section at a distance from the section axis. The first auxiliary circuit has controllable tuning elements therein and depending on the control state of the tuning elements, a radio-frequency excitation current flowing in the first sub-section causes an auxiliary current in the auxiliary circuit section leading the excitation current, an auxiliary current in the auxiliary circuit section lagging the excitation current, or no auxiliary current.

The coupling section alternatively can be a component of the sub-section or an element different from the sub-section. In the first case, a

simpler, more compact and more cost-effective assembly of the antenna element results, in the second case less feedback of the current in the antenna element occurs.

In the minimum case, it can be sufficient when the antenna element has a single auxiliary circuit. Preferably, however, it has a second sub-section, axially offset with regard to the first sub-section, with a second auxiliary circuit adjacent thereto. The second auxiliary circuit has a coupling section and an auxiliary circuit section. The second auxiliary circuit is inductively coupled to the second sub-section via the coupling section, and the auxiliary circuit section proceeds parallel to the second sub-section, at a spacing from the section axis. The second auxiliary circuit has controllable tuning elements therein, and depending on the control state of the tuning elements, a radio-frequency excitation current flowing in the second sub-section causes an auxiliary current in the auxiliary circuit section leading the excitation current, an auxiliary current in the auxiliary circuit section lagging the excitation current, or no auxiliary current.

Actually, normally more than two sub-sections are each arranged adjacent to their own auxiliary circuit.

The auxiliary circuits preferably are inductively decoupled from one another. This can be achieved, for example, by the auxiliary circuits having an overlap region.

The auxiliary circuits furthermore are preferably controllable independently of one another. A flexible operation of the antenna element thereby results.

Typical antenna arrangements for magnetic resonance applications employ a number of antenna elements disposed parallel to one another. In the case of the present invention, the elements individually are fashioned as described above. The antenna elements can be fashioned rod-shaped and arranged around an arrangement axis.

The antenna arrangement can form a saddle coil, but the antenna elements preferably are coupled with one another at their ends by ferrules (rings), i.e. the antenna arrangement is fashioned as a birdcage resonator. This embodiment is often used, particularly if the antenna arrangement has dimensions for use as a whole-body coil. Coupling of the antenna elements to a radio-frequency shield surrounding the antenna arrangement is also possible.

DESCRIPTION OF THE DRAWINGS

FIG. 1 shows an inventive antenna arrangement in perspective representation.

FIG. 2 shows the antenna arrangement of FIG. 1 in cross-section.

FIG. 3 shows an antenna element for use in the inventive antenna.

FIG. 4 shows an alternative embodiment of such an antenna element.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

As shown in FIGS. 1 and 2, an antenna arrangement for magnetic resonance applications has a number – in the present case eight – of identically fashioned antenna elements 1. The antenna elements 1 are rod-shaped and arranged around an arrangement axis. In the present case, they are coupled with one another at their ends by ferrules 1'. The antenna

elements 1 run parallel to the arrangement axis 2, and thus are also parallel to one another. The antenna arrangement thus forms a birdcage resonator.

The antenna elements 1 are – see FIG. 2 – surrounded by a radio-frequency shield 3. This is particularly desirable when the antenna arrangement is fashioned as a whole-body antenna of a magnetic resonance system, as in the present case.

A current can be fed into the antenna arrangement from a control and evaluation device 4 via a power amplifier 5, a transmission/reception diplexer 6, and a current divider 7. A 90° phase shift ensues via the current divider 7 in one of the in-feed branches. The antenna arrangement therefore is excited such that it generates a circularly polarized radio-frequency field. A subject (not shown) – for example a person – thus can be excited to magnetic resonance by this radio-frequency field.

Excited magnetic resonances signals can also be received (detected) by the antenna arrangement. A received magnetic resonance signal can then be supplied to the control and evaluation device 4 via the current divider 7 (that acts as a combiner in the reception mode), the transmission/reception diplexer 6 and a pre-intensifier 8. It can be progressively evaluated by the control and evaluation device 4.

A radio-frequency current (also called as an excitation current I in reception mode) flows in the antenna elements 1 both in the case of transmission and in the case of reception.

As shown in FIG. 3, each antenna element 1 extends along a section axis 9. Each antenna element 1 has a first sub-section 10 and a second sub-

section 10'. The sub-sections 10, 10' extend along the section axis 9, but they are axially offset relative to one another. Generally, more than two sub-sections 10, 10' axially offset relative to one another are present, for example four sub-sections 10, 10'.

Each sub-section 10, 10' is adjacent to its associated auxiliary circuit 11, 11'. The auxiliary circuits 11, 11' are identically fashioned and cooperate with the first and second sub-section 10, 10' respectively. Due to this identical design and the identical operation, only the first auxiliary circuit 11 described in detail below. The embodiments with regard to the first auxiliary circuit 11 are also analogously applicable to the second auxiliary circuit 11' (and, as the case may be, also further auxiliary circuits).

As shown in FIG. 3, the first auxiliary circuit 11 has tuning elements 14, 15 that can be controlled by the control and evaluation device 4 independently of one another via switches 16, 17. The switches 16, 17 can be, for example, PIN diodes or relays.

When the switch 16 is closed and the switch 17 is open, the resonant frequency of the first auxiliary circuit 11 is below the frequency (which is the selected magnetic resonance frequency) of the excitation current I that flows in the antenna element 1. The excitation current I therefore causes an auxiliary current i in the first auxiliary circuit 11 (as well as in the corresponding auxiliary circuit section 13) that leads the excitation current I.

When, in reverse, the switch 16 is open and the switch 17 is closed, the resonant frequency of the first auxiliary circuit 11 is higher than the resonance frequency. In this case, via the excitation current I, an auxiliary

current i is caused in the first auxiliary circuit 11 (and the associated auxiliary circuit section 13) that lags the excitation current I.

When both switches 16, 17 are open, the excitation current I can cause no auxiliary current i in the first auxiliary circuit 11.

The second auxiliary circuit 11', or more specifically switches 16', 17', can be controlled independently of the control state of the first auxiliary circuit 11, or more specifically switches 16, 17. The auxiliary circuits 11, 11' thus can be controlled independently of one another.

As shown in FIG. 3, the auxiliary circuits 11, 11' have an overlap region F. Due to this overlap region F, the auxiliary circuits 11, 11' are inductively decoupled from one another.

The design of the antenna element of FIG. 4 substantially corresponds to the design of the antenna element of FIG. 3. The single difference is that the coupling sections 12, 12' for the sub-sections 10, 10' are different elements in the antenna element 1 according to FIG. 3, while the coupling sections 12, 12' are components of the sub-sections 10, 10' in the representation according to FIG. 4. Also, for better clarity, the representation in FIG. 4 is separate from the control and evaluation device 4.

Thus, in the transmission mode, the fields caused by the individual antenna elements 1 can be locally influenced by control of the auxiliary circuits 11, 11'. In the reception mode the local sensitivity of the antenna elements 1 can be directed toward the field to be detected by control of the auxiliary circuits 11, 11'. The influence on the excitation current I flowing in the entire antenna element 1 remains negligibly small. The field emitted or

acquired by the antenna element 1 in the region of the respective sub-section 10, 10' corresponds, however, with the entire current flowing in the respective sub-sections 10, 10' of the antenna element 1. Thus the excitation current I or the overlay of excitation current I and auxiliary current i or i' depends on control of the switches 16, 17, 16', 17'. Thus the total current (I or I + i or I + i') flowing locally in the respective sub-section 10, 10' of the antenna element 1 can be adjusted.

As shown in FIGS. 3 and 4, the antenna element 1 is coupled to the radio-frequency shield 3 via capacitors 18. This design represents an alternative to the coupling of the antenna elements 1 via the ferrules 1'.

A shadow effect in generated magnetic resonance images thus can be prevented by the inventively fashioned adjacent antenna elements. The conditions under which the individual auxiliary circuits 11, 11' are to be coupled to the sub-sections 10, 10', and thus which of the switches 16, 17, 16', 17' is to be closed, can be determined by simple tests, in connection with considerations of symmetry, as warranted.

Although modifications and changes may be suggested by those skilled in the art, it is the intention of the inventor to embody within the patent warranted hereon all changes and modifications as reasonably and properly come within the scope of his contribution to the art.